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IMPROVEMENTS IN SILICON SOLAR CELL COVERGLASS ASSEMBLY AND PACKAGING USING FEP TEFLON

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ABSTRACT

Two techniques are described for improving silicon solar cell cover glass assembly and packaging by the use of FEP Teflon. One method utilizes Teflon as an adhesive for cementing standard cover glasses to the silicon solar cells. Because of the resistance of the Teflon to UV radiation, the UV filter on the cover glass can be eliminated. Also, labor for mounting the cover glass is reduced. Covered cells produced in this manner are more readily fabricated and have a slightly higher power output initially as compared with cells produced by present techniques.

The second method utilizes Teflon both as the cover material and as an adhesive for mounting the solar cells to a flexible substrate. A significant decrease in cost is anticipated for arrays fabricated in this manner. Some of the characteristics of a completed array would be: lightweight, flexible, insulated, completely sealed and breakage resistant.

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SUMMARY

Two techniques are described for improving silicon solar cell cover glass assembly and packaging by the use of FEP Teflon. One method utilizes Teflon as an adhesive for cementing standard cover glasses to the silicon solar cells. Glass covered cells produced by this method are more readily fabricated and have a slightly higher power output than cells produced by present techniques.

The second method utilizes Teflon both as the cover material and as an adhesive for mounting the solar cells to a flexible substrate. Solar cell arrays fabricated by this method can realize a significant decrease in cost. The main factors in the cost reduction are the elimination of the labor required to cover each cell individually with a cover glass and the cover glass itself, and a reduction in the effort required to mount the solar cells on a substrate. Some of the characteristics of a completed array would be lightweight, flexible, insulated, completely sealed and breakage resistant.

Preliminary tests under electron irradiation, UV irradiation, humidity exposure and vacuum thermal cycling are encouraging.

INTRODUCTION

Large solar cell arrays are being considered for some future missions that will require power levels in the multikilowatt range. One such application, a space station, will require about 25 kw of power. Of special interest to these applications are arrays utilizing flexible substrates which permit them to be rolled up or folded up for storage during the launch phase. References 1, 2 and 3 present the results of some of the studies that have been done on roll up arrays. In the typical array concept 2 × 2 cm 8-mil thick silicon cells are glued to a flexible plastic sheet, usually Kapton. Radiation protection is provided by 3- to 6-mil thick covers of glass or fused silica attached to the front of the cells. The cover is applied to each cell individually by cementing with an adhesive. To protect the cells in the stowed position some sort of cushion layer is generally provided between the layers of cells.

The Lockheed Palo Alto Research Laboratory, Palo Alto, California has done some preliminary work with FEP Teflon as a solar cell cover (ref. 4). FEP Teflon has some properties which make it an attractive candidate for use with solar cells. These properties are: flexibility, tolerance to electron and UV radiation (ref. 5), high light transmission, ability to bond to itself and other materials under heat and pressure, and low cost.

Two techniques that take advantage of the FEP Teflon properties are being investigated at the NASA Lewis Research Center in an effort to develop better and cheaper ways to make large solar cell arrays. This report describes the techniques and some of the preliminary results obtained.

The first method utilizes FEP Teflon as an adhesive for cementing standard cover glasses to silicon solar cells. The second method utilizes the FEP Teflon both as the cover material for radiation protection and as an adhesive for mounting the solar cells to a flexible substrate for fabricating lightweight, insulated, flexible silicon solar cell arrays.

APPARATUS

The equipment used to bond cover glasses to silicon solar cells and to fabricate arrays or modules with FEP Teflon is shown in figures 1 and 2. The laminating press, figure 1, is used as a heat source and container for the platens shown in figure 2. In order to produce samples which were free of voids and eliminate breakage of the solar cells it was found necessary to use a combination of vacuum and pressure.

PROCEDURE

All materials used are first cleaned by boiling in alcohol for one minute. The laminating press is closed and preheated to about 300°C. The platens are opened and placed on a bench and vacuum is applied to the porous base. A 5-mil thick sheet of porous Armalon is placed over the base to act as a release agent to prevent FEP Teflon from sticking to the base.

Method I. FEP Teflon as an Adhesive for Cementing Standard Cover Glasses to Silicon Solar Cells

Six-mil fused quartz covers coated on one side with an antireflection (AR) coating are placed with the coated side down on the Armalon. Next,

a 2-mil thick sheet of type 20C FEP Teflon (treated on both sides for better bonding) is placed over the cover glasses. The solar cells are then placed over the FEP Teflon and aligned with the cover glasses. Next a 1-mil sheet of skived TFE Teflon is placed on top to act as a release agent. Finally a 5-mil sheet of aluminum is set over the entire platen and sealed against the "O" ring. This final sheet acts as a vacuum seal and also as a means of applying pressure to the samples. The top half of the platen is put into position and the two halves are bolted together.

The laminating press is opened and the platens are inserted. The press is then closed and a hydraulic pressure of about 300 psi is applied. This pressure is not applied to the samples but only to the platens to hold them together. Nitrogen gas pressure up to 100 psi is applied to the top half of the platen, and therefore to the samples by way of the aluminum sheet. The platens are allowed to heat to about 290°C. Neither the pressure nor the temperature for lamination have been optimized. The manufacturers recommendations were used in this investigation. The samples remain at 290°C for about five minutes. At this time the heaters are turned off and cold water is allowed to flow through the press for quick cooling. After cooling, the platens are removed and opened and the completed samples are removed. The cells are then separated and the excess material is trimmed from the cell edges and contacts.

Method II. FEP Teflon Both as the Cover Material and as an Adhesive for Mounting the Solar Cells to a Flexible Substrate

This discussion will cover the fabrication of modules which are in effect small arrays. The solar cell modules can be interconnected electrically by either ultrasonic bonding, thermal diffusion bonding or soldering. Most of the modules used in this work were 3 cells in parallel by 10 cells in series. They were made up of 8-mil thick solderless silicon solar cells with expanded silver mesh that were interconnected by thermal diffusion bonding by the Boeing Company.

The size of the cells and modules and the thickness of the various layers used are not limited to those discussed in this report. The techniques discussed are equally applicable to larger or smaller cells and thicker or thinner cells and layers of Kapton and FEP Teflon.

The procedure used to fabricate the modules is essentially the same as discussed above. First a 1-mil thick sheet of Kapton (the substrate) is placed on the Armalon. A 2-mil thick sheet of type 20C FEP Teflon is then placed over the Kapton. This Teflon layer acts as the adhesive for bonding the solar cells to the substrate. The solar cells which were previously interconnected are then placed over the Teflon. A 5-mil thick sheet of type C FEP Teflon (treated on one side for better bonding) is placed over the solar cells with the treated side facing the cells. The other steps are identical with those discussed above beginning with the skived Teflon layer. Figure 3 shows the various layers in the platen before lamination. The layers are rolled back for clarity.

After the completed module is removed, excess material is trimmed from the edge. To ensure that the module remains sealed an edge of about 1/16 inch is retained. A completed module is shown in figure 4. To fabricate larger arrays the packaged modules would be electrically connected and the interconnections could be packaged in the same fashion as the modules.

DISCUSSION

Method I

Preliminary electrical measurements on the solar cells before and after applying the cover glass indicate no change in the short circuit current, reverse leakage current, contact resistance and junction characteristics. These results are for cells coated with SiO. Cells covered in this manner have an advantage over cells with glass covers cemented on with conventional adhesives. Response to blue light can be retained because a UV filter is not required. An additional benefit is obtained when the cells are exposed to radiation since the blue response of the cells is least affected by the radiation (ref. 6). Tolerance limits of the cells to radiation have not been fully investigated but preliminary results indicate no physical damage to the FEP Teflon after the cells have been exposed to 10^{15} 1 MeV electrons/cm^2 in vacuum.

Several cells were exposed to UV radiation of wavelengths less than 0.3 μm at an intensity of 7.5 suns for a total exposure of about 3600 equivalent sun hours. The short circuit current decreased about 3 percent.

Three cells were also alternately dipped and removed from liquid nitrogen five times without any change in their physical appearance. There was no separation or cracking of the glass. The cells were then dipped five times in boiling water for two minutes. Again no change was noticed.

Method II

Essentially identical results were observed for modules prepared by method II as with cells prepared by method I. An additional test performed on the modules was a vacuum thermal cycling test. For this test two six-cell series string modules were interconnected at Lewis and packaged by method II. The interconnections were made of 1-mil aluminum foil. The foil was not physically bonded to the cell but held in place by the packaging. These modules were exposed to 1016 vacuum thermal cycles. The temperature reached about 40°C during the lighted portion of the cycle (1 hour) and about -125°C during the dark portion of the cycle (1/2 hour). Current-voltage characteristics of the module measured before, during and after the cycling indicated no changes in the cells. No change in physical appearance was observed. Eight single cells packaged by method II exposed to 90 percent relative humidity at room temperature for one month also indicate no changes.

The results discussed above are preliminary. Further, more extensive testing is planned.

CONCLUDING REMARKS

Two techniques for improving silicon solar cell cover glass assembly and packaging by the use of FEP Teflon have been described. Method I produces glass covered cells which are more readily fabricated and have

a slightly higher power output than cells produced by present techniques. Solar cell arrays fabricated by the use of method II can realize a significant decrease in cost. The main factors in the cost reduction are the elimination of the labor required to cover each cell individually with a cover glass and the cover glass itself, and a reduction in the effort required to mount the solar cells on a substrate. Some of the characteristics of a completed array would be: it is lightweight, flexible, insulated, protected from radiation front and back, completely sealed and breakage resistant. In addition when the array is rolled up or folded for storage, a cushion may not be needed between the layers of cells.

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LAMINATING PRESS

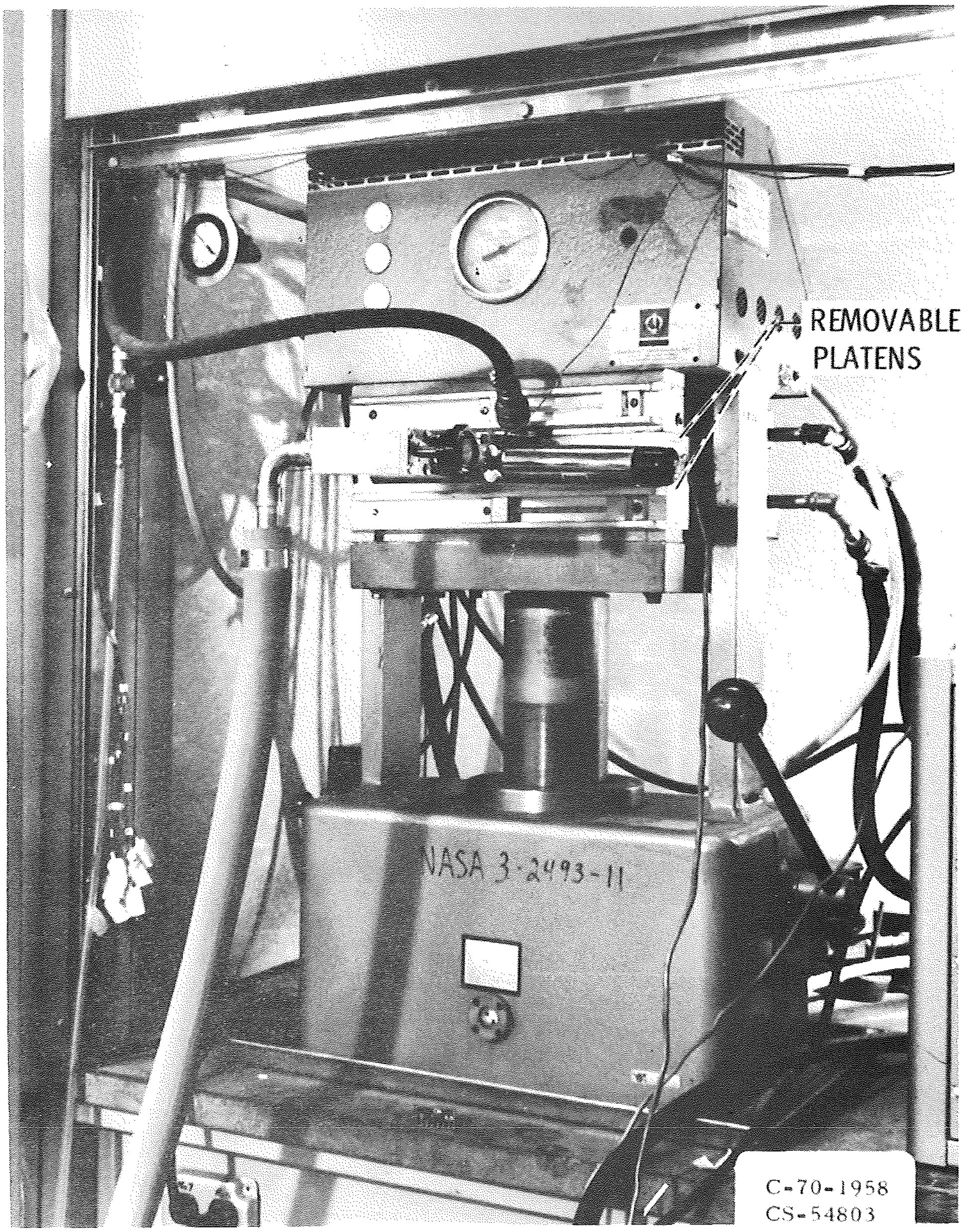

Fig. 1

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PLATENS

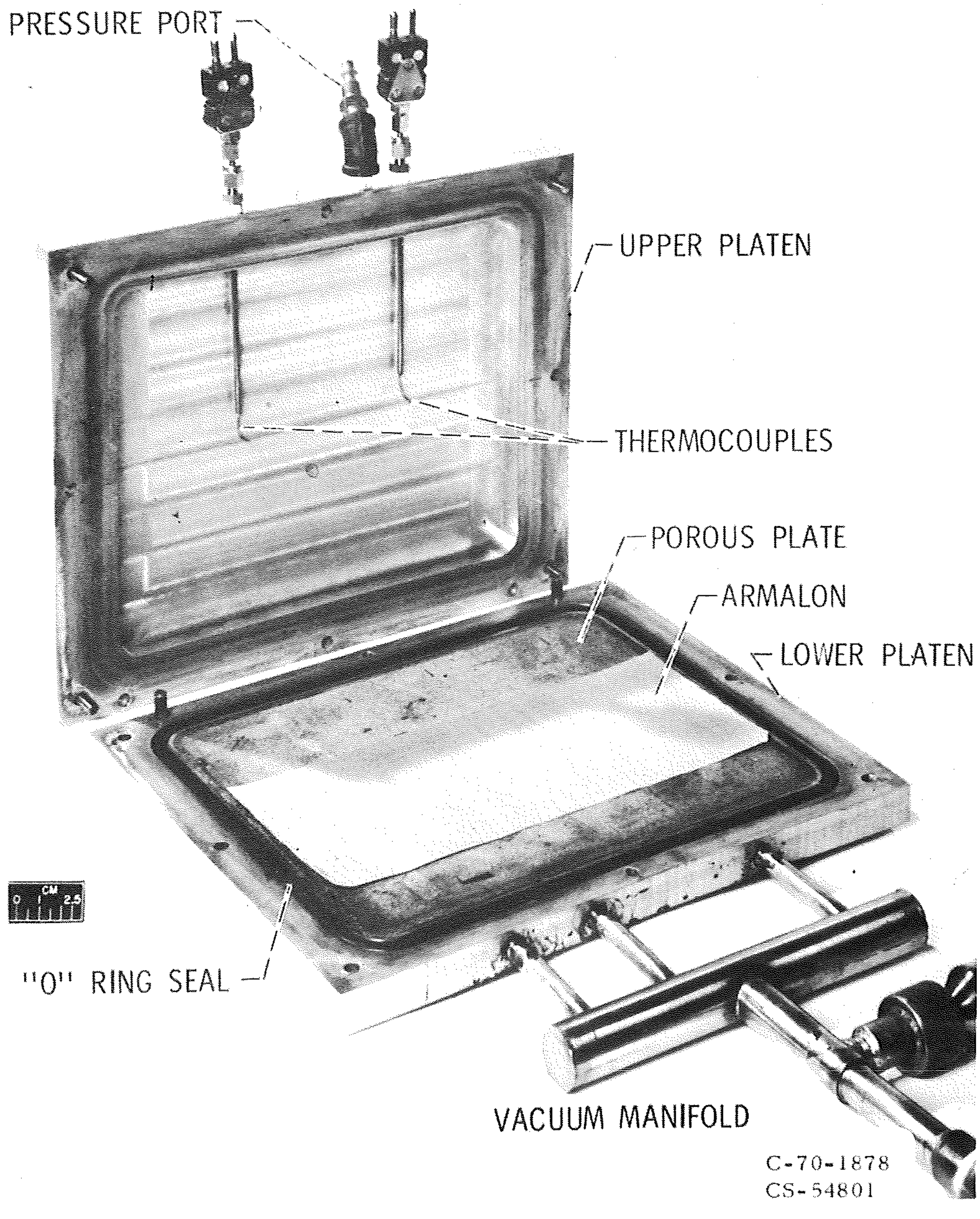

Fig. 2

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SILICON SOLAR CELL MODULE PREPARED FOR LAMINATION

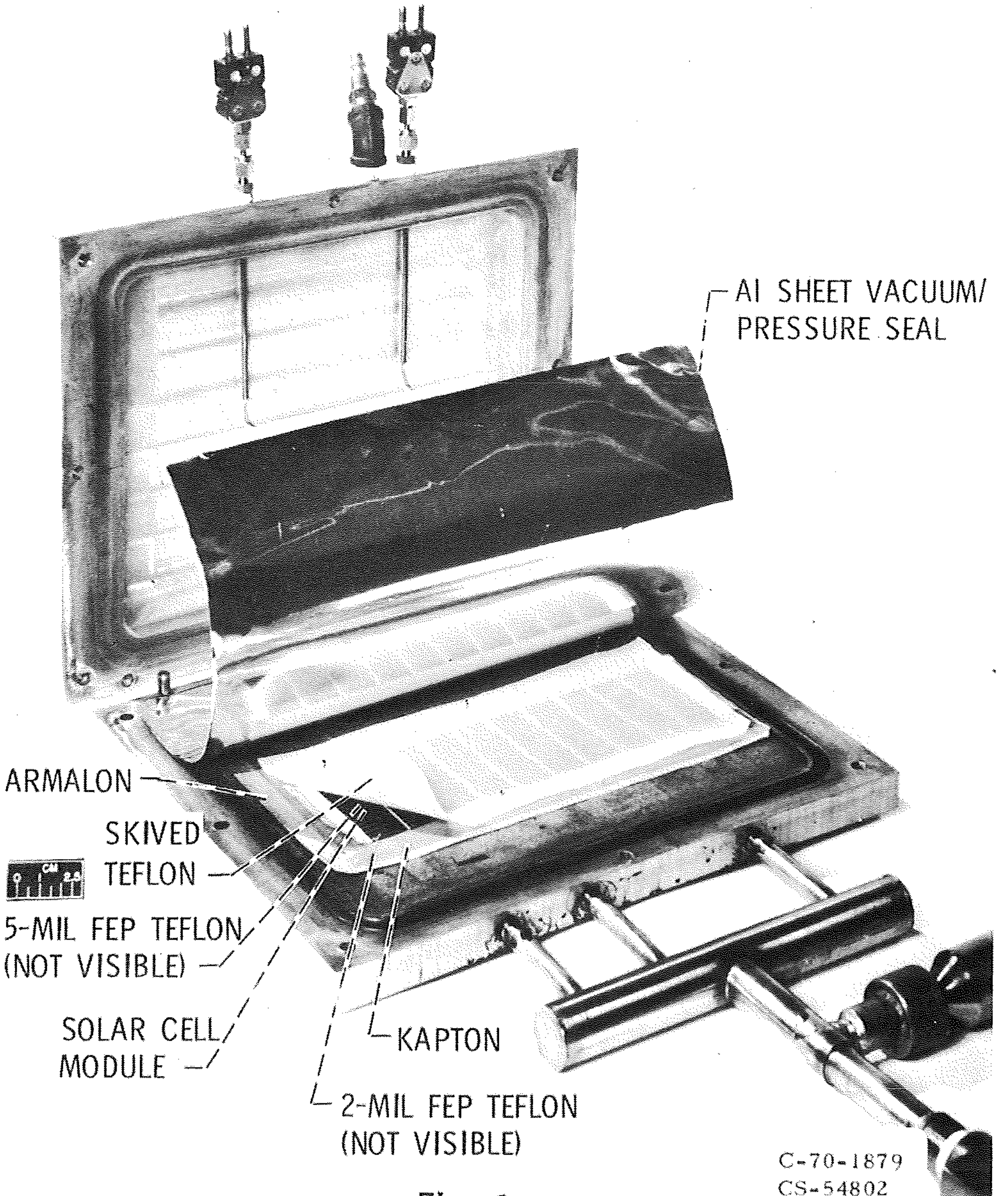

Fig. 3

COMPLETED SILICON SOLAR CELL MODULE

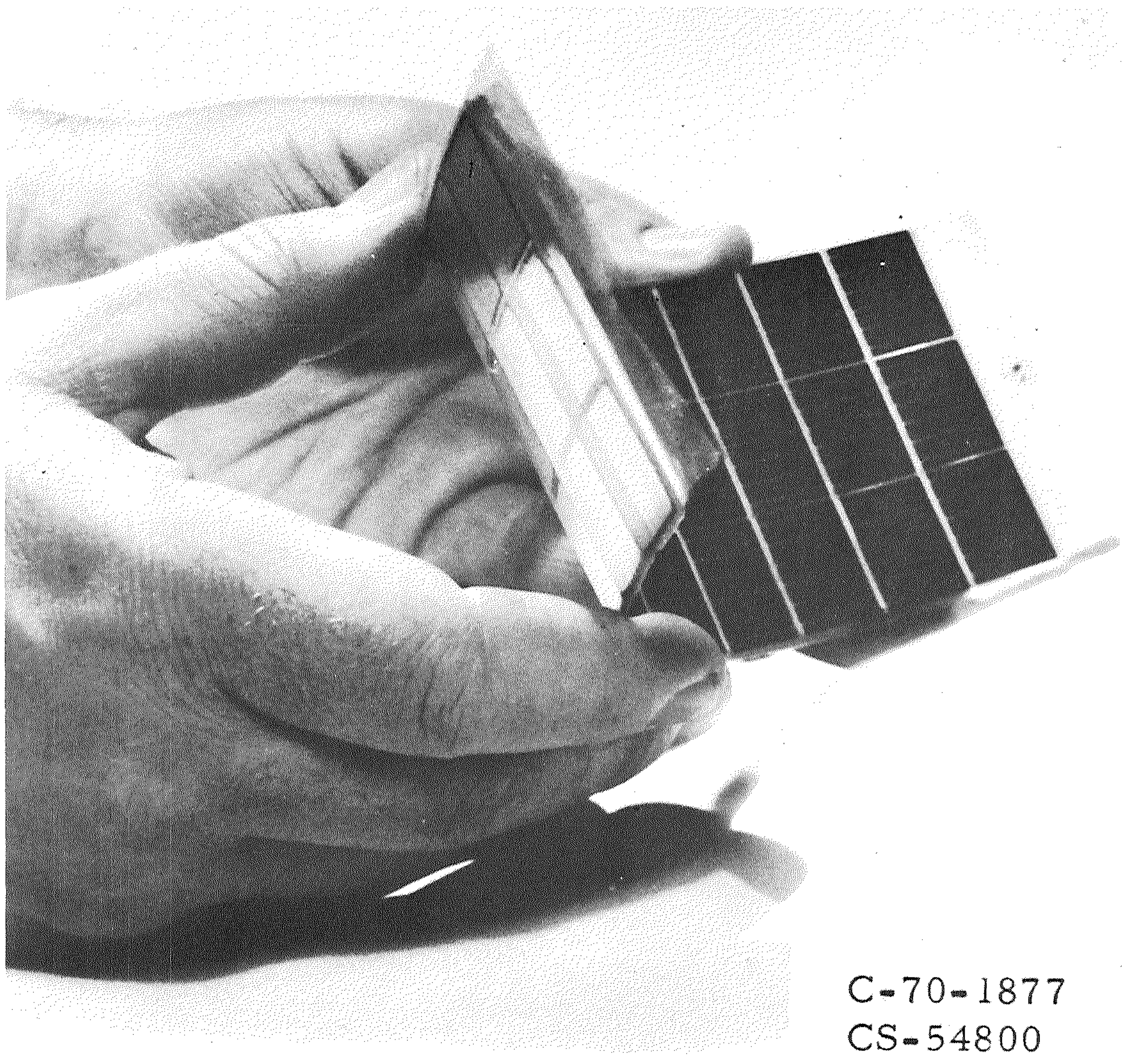

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Fig. 4